The joint contribution of neighborhood poverty and social integration on mortality risk in the United States

By: Andrea Fleisch Marcus, Sandra E. Echeverria, Bart K. Holland, Ana F. Abraido-Lanza, and Marian R. Passannante

Marcus A, Echeverría SE, Passanante M, Holland B, Abraido-Lanza AF. The joint contribution of neighborhood poverty and social integration on mortality risk in the United States. *Annals of Epi.* 2016 March; 26 (4):261-266. https://doi.org/10.1016/j.annepidem.2016.02.006

Abstract:

Purpose: A well-established literature has shown that social integration strongly patterns health, including mortality risk. However, the extent to which living in high-poverty neighborhoods and having few social ties jointly pattern survival in the United States has not been examined. **Methods:** We analyzed data from the Third National Health and Nutrition Examination Survey (1988–1994) linked to mortality follow-up through 2006 and census-based neighborhood poverty. We fit Cox proportional hazards models to estimate associations between social integration and neighborhood poverty on all-cause mortality as independent predictors and in joint-effects models using the relative excess risk due to interaction to test for interaction on an additive scale. **Results:** In the joint-effects model adjusting for age, gender, race/ ethnicity, and individual-level socioeconomic status, exposure to low social integration alone was associated with increased mortality risk (hazard ratio [HR]: 1.42, 95% confidence interval [CI]: 1.28–1.59) while living in an area of high poverty alone did not have a significant effect (HR: 1.10; 95% CI: 0.95–1.28) when compared with being jointly unexposed. Individuals simultaneously living in neighborhoods characterized by high poverty and having low levels of social integration had an increased risk of mortality (HR: 1.63; 95% CI: 1.35–1.96). However, relative excess risk due to interaction results were not statistically significant. **Conclusions:** Social integration remains an important determinant of mortality risk in the United States independent of neighborhood poverty.

Keywords: Social determinants of health | Social support | Neighborhood | Mortality

Article:

Introduction

Several decades of research has shown that social relationships have a profound effect on health [1], [2], [3], [4], [5], [6], [7], [8], and social integration, defined as engagement with

others through social ties and institutional connections, has been associated with a range of chronic health conditions and mortality [1], [7], [9], [10]. Berkman and colleagues [11] developed a conceptual framework for understanding how social relationships influence health and described a cascading effect of social contexts on relationships, health behaviors, and ultimately population health.

A similarly robust literature links neighborhood of residence to health showing that living in deprived areas increases risk of cardiovascular disease, physiological stress, health-damaging behaviors, and mortality [12], [13], [14], [15], [16], [17]. Moreover, there has been an increased interest in elucidating how neighborhood contexts shape the formation and maintenance of social relationships [4], [18], [19], [20], [21], [22] and how they interact with individual-level exposures to potentially modify the development of disease [15], [23], [24].

Despite the consistent and large body of evidence on neighborhoods and social integration as independent predictors of health, fewer studies have explicitly examined how social integration is patterned by broader neighborhood contexts [25], [26], [27], [28], [29]. Investigations of whether neighborhood conditions and social integration may have a synergistic effect on health seem to be missing entirely. Evidence from the Whitehall cohort study [30] showed that men with higher socioeconomic position (SEP) had better quality social relationships and better health than those with lower SEP; the association between SEP and mortality was partly explained by social integration. However, this and other research investigating social integration's impact on mortality did not include neighborhood socioeconomic condition [30], [31].

Informed by the evidence base, we examined if neighborhood poverty and social integration synergistically influenced mortality risk in a national sample of the US population. We used the conceptual framework proposed by Berkman et al. [11] to guide the study and hypothesized that individuals living in impoverished neighborhoods and having low levels of social integration have a mortality risk greater than what may be expected from the additive effects of exposure to each factor alone.

Material and methods

Data sources

Data are drawn from the Third National Health and Nutrition Examination Survey (NHANES III). The survey, conducted by the Centers for Disease Control and Prevention, used a complex, multistage, stratified sampling design intended to recruit a nationally representative sample of the non-institutionalized, civilian US population. NHANES III was conducted from October 1988–1994 and included individuals from age 2 months. Data collection consisted of an in-home interview and a series of examinations [32]. The data for the present study were taken from the household interviews.

The NHANES III Linked Mortality File contains follow-up data for NHANES III participants through December 31, 2006. Mortality status was identified using the National Death Index,

primarily through probabilistic record matching. This is considered to be a reliable source of mortality follow-up [33].

NHANES III participants' home addresses were geocoded and matched to 1990 Census tracts. Data were geocoded by the Westat Geocoding Service Center for the National Center for Health Statistics (NCHS) [34] Geocoded NHANES III data are available for restricted use which assures confidentiality of the study participants. The 1990 Census file used for this study was compiled by The Public Health Disparities Geocoding Project at the Harvard School of Public Health [35], [36]. It contains a measure of the percent of residents in each census tract living below the poverty line. In addition to review and approval by the Research Data Center at NCHS, the study protocol was approved by the authors' University Institutional Review Board.

Measures

Social integration. Previously published studies [9], [37], [38] have used items from NHANES III to create a modified Social Network Index (SNI) that captures the four domains first assessed by Berkman and Syme [1]. This index was chosen for use in the present study to allow our work to be placed within the context of the research that has already been done that uses this modified SNI with the NHANES III [9], [37], [38], [39]. It is computed as follows: 1 point was assigned for married or living as married, 1 point was assigned for >156 contacts with friends and family in the past year, 1 point was assigned if at least four religious services were attended in the past year, and participation in a voluntary organization was assigned 1 point. A total score, ranging from 0 to 4, was created by summing the four items. This approach has been shown to have good predictive validity in that it is associated with health outcomes in a similar manner to the original SNI [1], [9], [37], [38]. The SNI was dichotomized into high (2–4) and low (0–1), where the high-score category represented a favorable level of social integration. This categorization is consistent with other studies where 0 and 1 have been combined to create a low social integration group and compared with the remaining categories [9], [10], [38]. We also conducted sensitivity analyses to assess if results differed based on our choice of categorization (data not shown). We found minor differences in risk across the original categories of 2, 3, and 4 and thus combined these categories to represent “high” social integration. Furthermore, creating two categories of social integration facilitated fitting the joint-effect models described below.

Neighborhood socioeconomic condition. Census tracts served as proxies for neighborhoods. Census tracts are commonly used in the investigation of area-level socioeconomic factors due to their consistent use in government and health research and relevance to public policy decisions for resource allocation [27], [36], [40], [41]. Neighborhood socioeconomic condition was measured via neighborhood poverty, which has been shown to be a reliable measure of socioeconomic inequality in health studies [35]. A two-level classification was created based on the federal definition of poverty areas [40], [42]. Low-poverty areas were defined as <20% of residents living below the federal poverty line and high-poverty areas where ≥20% of the residents live below poverty.

Mortality. The outcome of interest was time-to-death due to all-cause mortality or, more specifically, person-months of follow-up from the interview to December 31, 2006. There were 12–18 years of follow-up for the sample depending on the year of NHANES interview with a

mean of 167 months (95% confidence interval [CI]: 162–172) for the weighted sample. There were 20,024 participants eligible for the linkage and 5,360 deaths.

Covariates. Age, sex, race/ethnicity, and individual SEP were adjusted for in the multivariable models due to their demonstrated associations with mortality. Race /ethnicity was self-reported and classified as non-Hispanic white, non-Hispanic black, Mexican-American, and other [32]. Individual SEP was based on years of education completed (<8, 9–11, 12, and 13+ years) and the participants' household poverty income ratio (PIR; <1, 1–1.99, 2–2.99, 3–3.99, and >4) [15], [25], [27], [32], [43].

Statistical analysis

Descriptive statistics summarize the characteristics of the whole sample and by neighborhood poverty. We used Cox proportional hazards regression to model the relationship between SNI and time-to-death while adjusting for covariates. If no death was recorded, subjects were censored at the end of the follow-up period. The proportional hazards assumption was examined using Kaplan-Meier curves [44]. We assumed that death occurred in this sample at a steady rate equal to that in the general US population and that participation did not alter their mortality risk.

In planning these analyses, we considered how to address both the multilevel nature of the study variables and the complex sample design of NHANES III. We opted to use the sample design variables but assume that the neighborhoods are adequately captured because the primary sampling units were areas which contain several census tracts and are the higher-level grouping [28].

Effect modification was assessed in two ways. First, the Cox regression models were stratified by level of neighborhood poverty to examine differences in the hazard ratios (HRs) which assesses multiplicative interaction between neighborhood poverty and social integration. Next, a four-level dummy variable was inserted into the regression model combining social integration and neighborhood poverty to assess additive interaction [45]. The referent category in this joint-effects model consisted of individuals with the least risk, that is, high SNI and low neighborhood poverty (labeled dR). The other three categories were high SNI/high neighborhood poverty (labeled d1), low SNI/low neighborhood poverty (labeled d2), and low SNI/high neighborhood poverty (highest risk group labeled d3). While the referent group represents the absence of the main effects, the high risk group represents the joint effects and the other two variables represent the independent effect of each risk. The HRs of each group compared with the referent group are reported and were used to calculate the following measures of deviation from additivity [45], [46]: relative excess risk due to interaction (RERI), the synergy index, and attributable proportion due to interaction (AP). These measures were calculated as follows—$RERI = HR_{d3} - HR_{d2} - HR_{d1} + 1$; $S = HR_{d3} - 1/(HR_{d2} - 1) + (HR_{d1} - 1)$; $AP = RERI/HR_{d3}$. The RERI and AP are equal to 0 if there is no effect modification, greater than 0 for positive or less than 0 for negative, and the synergy index is equal to 1 with exact additivity. CIs and *P*-values were calculated using a spreadsheet developed by Knol [47] for the delta method of standard error estimation.

The full sample of adults interviewed as part of NHANES III and eligible for subsequent follow-up was 20,024. Respondents were excluded if their addresses at the time of the interview were

not able to be geocoded (n = 2778). To ensure that individuals had an opportunity to have their health shaped by the neighborhood where they lived, those who lived in their city/town/area for less than one year were excluded (n = 1202). The final analytic sample consisted of 16,044 respondents. In addition, the sample size is less than 16,044 for analyses where observations had missing data. A total of 1699 observations were missing income data, and these cases were more likely to be from the extremes in the age spectrum, racial/ethnic minorities, less educated, and lived in their areas for shorter periods of time when compared with those where income is provided. All analyses were conducted using SUDAAN, version 10 [48] and were weighted to account for the complex sample design using the appropriate demographic weight, strata, and primary sampling unit variables.

Table 1. Weighted descriptive summary statistics for the total sample (n = 16,044) and by neighborhood poverty category

Variable	Total sample % (SE)	0–19.9% Neighborhood poverty	≥20% Neighborhood poverty
All	100 (0.0)	81.3 (1.2)	18.7 (1.2)
Individual-level predictors			
Age groups			
17–19 years	4.8 (0.35)	4.5 (0.4)	6.0 (0.51)
20–29 years	19.8 (0.81)	18.6 (0.8)	24.8 (1.55)
30–39 years	23.7 (0.75)	24.0 (0.9)	22.6 (1.33)
40–49 years	17.9 (0.62)	18.4 (0.7)	15.5 (1.06)
50–59 years	11.9 (0.41)	12.4 (0.5)	9.7 (0.63)
60–69 years	10.9 (0.49)	11.0 (0.6)	10.2 (0.74)
70–79 years	7.6 (0.41)	7.7 (0.5)	7.4 (0.62)
80 + years	3.4 (0.29)	3.3 (0.3)	3.7 (0.39)
Sex			
Male	47.1 (0.47)	47.9 (0.6)	43.6 (0.92)
Female	52.9 (0.47)	52.1 (0.6)	56.4 (0.92)
Race/ethnicity			
Non-Hispanic white	73.6 (1.35)	80.7 (1.5)	42.4 (2.30)
Non-Hispanic black	12.3 (0.74)	7.4 (0.7)	33.5 (2.07)
Mexican-American	5.6 (0.48)	4.0 (0.5)	12.6 (1.06)
Other	8.5 (0.93)	7.8 (1.1)	11.5 (1.72)
Living below poverty (PIR < 1)	12.7 (0.90)	8.8 (0.8)	30.6 (1.86)
Highest year of school completed			
0–8 years	11.1 (0.61)	8.4 (0.6)	22.7 (1.11)
9–11 years	14.8 (0.60)	13.2 (0.7)	21.7 (0.90)
12 years	32.8 (0.83)	33.0 (1.0)	31.9 (1.48)
13 + years	41.3 (1.27)	45.4 (1.4)	23.8 (1.29)
How long lived in city/town/area			
Whole life	26.8 (1.14)	25.6 (1.3)	31.9 (1.35)
>20 years	26.6 (0.89)	26.6 (1.0)	26.8 (1.45)
11–20 years	15.6 (0.72)	16.1 (0.8)	13.3 (1.03)
5–10 years	14.6 (0.76)	15.2 (0.8)	11.9 (0.97)
3–4 years	7.6 (0.48)	7.6 (0.5)	7.6 (1.00)
1–2 years	8.7 (0.59)	8.8 (0.6)	8.4 (1.45)
Outcome			
Assumed deceased	17.2 (0.70)	16.3 (0.8)	21.2 (1.05)

SE = standard error.
This table displays column percentages.

Results

Table 1 presents the weighted descriptive statistics for the full sample and by neighborhood poverty groups. Approximately half of those sampled were women (53%), the majority (74%) were non-Hispanic white, and most (74%) had completed at least a high school education. Most of the sample lived above the poverty line (87%) and over half (53%) lived in their area of residence over 20 years or their whole life. Over half (61%) were between 20 and 49 years of age.

Those who lived in the highest poverty neighborhoods were more likely to be female, of a racial/ethnic minority group, live below the poverty line themselves and were less educated than those in the areas with less poverty. The mean person-months of follow-up are steady across categories of neighborhood poverty.

Figure 1*A* and Table 2 show the main effects of social integration on mortality. Individuals in the low SNI group had a consistently greater risk of death than the high SNI group. The group with low SNI scores had 1.30 (95% CI: 1.17–1.49) times the risk of death when compared with those with high SNI scores. After adjustment for age, gender, race, PIR, and years of education, the HR increased to 1.44 (95% CI: 1.31–1.58).

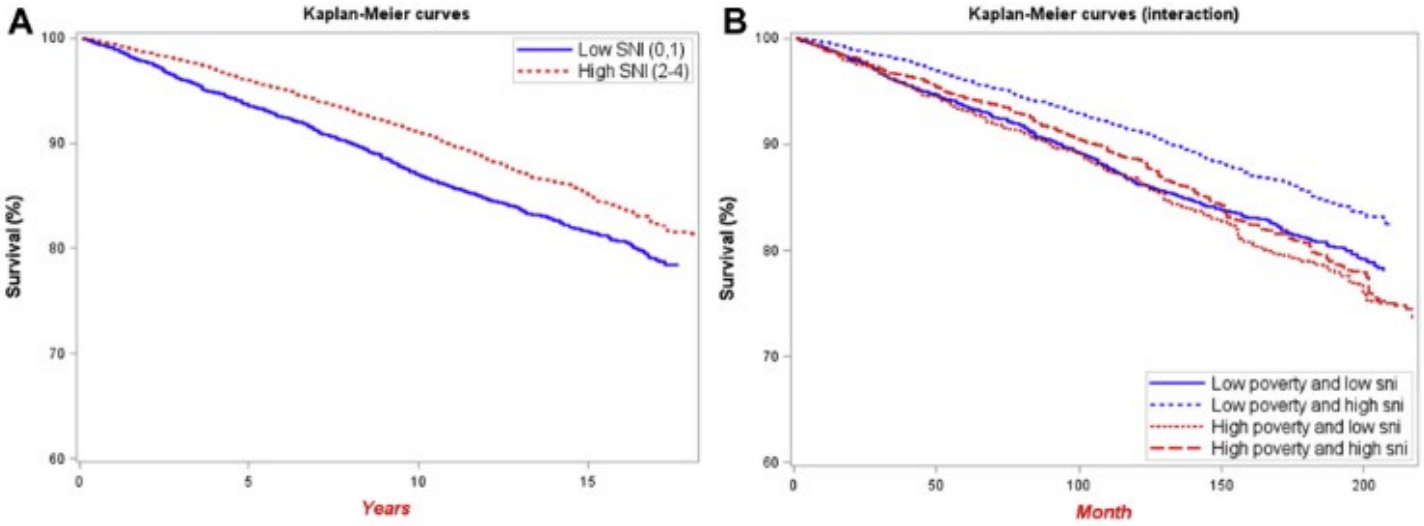

Fig. 1. (A) Cumulative survival for the social network index (SNI) groups. (B) Cumulative survival for effect modification of social network index score by neighborhood poverty.

Table 2. Cox proportional hazards regression models of the association between social network index score and mortality

Social network index	Model 1: crude model (unadjusted)		Model 2: adjusted for age, gender, race/ethnicity, individual poverty income ratio, and years of education	
	Hazard ratio	95% CI	Hazard ratio	95% CI
Low (0,1)	1.30	1.17–1.49	1.44	1.31–1.58
High (2–4)	1.00	ref	1.00	ref

When the adjusted models are stratified by neighborhood poverty (Table 3 marginals), those with low SNI scores within the low-poverty strata have a HR of 1.41 (95% CI: 1.27–1.58) and in the

high-poverty group the HR is 1.45 (95% CI: 1.18–1.78). These similar HRs provide little evidence for multiplicative interaction. The joint-effects model using the dummy variables (Table 3) showed that there was an increased risk for all three risk groups when compared with the referent. This is also depicted in the Kaplan-Meier curves (Fig. 1*B*). Individuals living in poor neighborhoods and having low levels of social integration had 1.63 times the risk of the referent group (95% CI: 1.35–1.96). A smaller risk of death was found for those living in nonpoor neighborhoods and having low levels of social integration (HR: 1.42; 95% CI: 1.28–1.59) and nonsignificant findings were observed for those living in high-poverty neighborhoods with high levels of social integration (HR: 1.10, 95% CI: 0.95–1.28). Although the RERI was positive, it was small and not statistically significant (RERI = 0.11, 95% CI: −0.25 to 0.46).

Table 3. Cox regression models examining the joint contribution of neighborhood poverty (NP) and social network index (SNI) score on mortality

Neighborhood poverty	High SNI score	Low SNI score	HRs (95% CI) for low SNI score within strata of NP
	HR (95% CI)	HR (95% CI)	
<20%	1.00 (referent)	1.42 (1.28–1.59) *P* = .0000	1.41 (1.27–1.58) *P* = .000
≥20%	1.10 (0.95–1.28) *P* = .1860	1.63 (1.35–1.96) *P* = .0000	1.45 (1.18–1.78) *P* = .000

Measures of effect modification on additive scale: RERI (95% CI) = 0.11 (−0.25 to 0.46) *P* = .55; SI = 1.21 (0.66–2.20) *P* = .54; AP = 0.07 (−0.14 to 0.27) *P* = .53.
HRs are adjusted for age, gender, race/ethnicity, individual poverty income ratio, education.

Discussion

We examined the joint effect of living in high-poverty neighborhoods and having low social integration on the risk of mortality in a national sample of US adults. We first confirmed the known association between social integration and mortality risk in our study population. We found that those who were socially isolated had a 44% increased risk of death than those more socially integrated. Adjusted hazards regression models showed that the joint effect of social integration and neighborhood poverty on mortality risk may be larger than the effect that is expected if each were acting independently. Specifically, individuals living in high-poverty neighborhoods and with low social integration had 1.63 times the risk of mortality compared with individuals living in low-poverty neighborhoods and having high social integration. However, tests of interaction on an additive scale using RERI were small and not statistically significant.

Few studies have examined if exposure to both low social integration and neighborhood poverty increases mortality risk above independent effects, and what the implications of this would be for public health action [49]. Our findings support prior work indicating an independent inverse relationship between social integration and mortality [1], [5], [30], [31], [50]. In adjusted hazards regression models, we also showed that individuals jointly exposed to high poverty and low social integration had an increased risk of mortality compared with the referent group of no exposure to either risk factor. Nonetheless, further examination of the public health impact of this association showed a small and statistically nonsignificant effect. We presented interaction results as recently advocated in the field to allow for a more complete assessment of potential interaction effects across multiple scales and strata [46], [51]. The use of these methods can

advance public health research by specifying groups of the population that are most at risk, and identifying potentially causal relationships to develop more targeted interventions [49].

The fact that our joint-effect results in hazards models (i.e., multiplicative interaction) suggested an increased risk but tests for additive interaction were not statistically significant, leaves open the question of the causal and public health implications of living in high-poverty neighborhoods and being socially isolated. Nonetheless, we suggest that a practical implication of our findings may be that supporting the development of neighborhood-level initiatives that address structural barriers such as racial segregation, housing stock and quality, employment opportunities, and quality education, while also working with residents to build community ties and bonds is a worthwhile investment (as evidenced by independent effects). The challenge remains for future research using stronger study designs (longitudinal data) to better elucidate how and if these types of interventions are causally related to health and if they lead to improved health outcomes.

In our study, neighborhood poverty had an independent effect on mortality as consistently shown in prior work [25], [27], [28], [29]. However, neighborhood poverty did not modify observed associations between social integration and mortality, and in fact social integration remained the stronger predictor of mortality in independent associations and in joint-effect models. Other work has suggested that neighborhood socioeconomic condition shapes social relationships and that this contribution can account for differences that are typically attributed to disparities by race/ethnicity [27], [28]. Future research is needed to examine if neighborhoods influence social integration by race/ethnicity and over the life course, which we were not able to examine in the present study. This research would help demonstrate if well-off neighborhoods provide the infrastructure for building social relationships that may be particularly relevant for racially/ethnically diverse and immigrant groups who often live in racially and/or ethnically segregated areas, or for the elderly who may be more limited in their mobility and hence rely on their immediate neighborhood context for well-being. Given that neighborhood poverty and social relationships are distal factors on the causal pathway to mortality and yet appear to exert an independent effect on health, improving these elements of the living environment could potentially offer substantial population health benefits [52]. As an example, Galea and colleagues [38] estimated that 323,044 deaths among adults in the United States in 2000 may have been attributable to low social integration and 39,330 deaths may have been attributable to area-level poverty, supporting our study findings of considerable mortality burden due to these social determinants.

Despite the strengths of our study, some limitations should be considered. One is that the covariates and main effect variables were captured at baseline only and thus time-dependent variables that may have influenced mortality were not assessed. For example, social integration and neighborhood of residence could change over time and evidence suggests that the timing of exposures determines health and differs over the life course [21]. Furthermore, the covariates that were included in our multivariable models likely do not account for all the potential confounders of the associations investigated. Residual and unmeasured confounding are important considerations. Another limitation is that we only examined all-cause mortality and not specific causes of death that may have indicated differential health effects of the neighborhood context and social relationships. We also chose to exclude missing data from the analysis instead of exploring methods of imputation for those values. This may have impacted

our findings as most of the missing data were for individuals living in neighborhoods with higher concentrations of poverty, likely underestimating our findings. Furthermore, the nature of the data did not allow us to test if the observed associations differed for distinct subgroups of the population marked by neighborhood segregation and/or varying levels or types of social relationships. Social integration is strictly a measure of the quantity of relationships and does not consider their quality, an important part of the path between social relationships and health. In addition, characterizing neighborhoods using census data at the census tract level may not correspond with respondents' assessment of the neighborhood (i.e., spatial mismatch). The effect of this lack of precision is unclear. However, the fact that we still found increased mortality risk despite these limits highlights the need for future research on this topic as it may have important implications for minority groups who tend to live in racially and/or ethnically segregated neighborhoods [40], [53], which often are characterized by poverty and low levels of social integration and beneficial social ties that can be used to effect change [16].

The strengths of this study include its large sample size and the inclusion of measures at the individual and neighborhood levels. To the best of our knowledge, this study is the first to include a national sample of the US population, introducing new evidence of the relationship between neighborhoods, social integration, and health. Associations were found in a diverse population and with distal social determinants—neighborhood poverty and social integration. In addition, our approach for examining how neighborhood poverty interacts with social integration is a methodological advancement in the literature that should stimulate further research on this and related topics.

Conclusion

Our results warrant further research to establish how living in poor neighborhoods structures social connections among individuals and how these exposures influence the duration of life of vulnerable groups.

Acknowledgments

The authors acknowledge Negasi Beyene and the Research Data Center at NCHS for their help in acquiring and accessing the data and for compiling the data set.

Support for preparing this article was provided, in part, by the National Institutes of Health (grants R25GM062454 and UL1TR000040). Part of this work was supported by Diversity Supplement R01CA49705-0281 and the Robert Wood Johnson Foundation, Active Living Research, New Connections Program.

References

[1] Berkman LF, Syme SL. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. Am J Epidemiol 1979;109:186e204.

[2] Cohen S, Doyle WJ, Skoner DP, Rabin BS, Gwaltney JM. Social ties and susceptibility to the common cold. JAMA 1997;277:1940e4.

[3] Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: a meta-analytic review. PLoS Med 2010;7:e1000316.

[4] House JS, Landis KR, Umberson D. Social relationships and health. Science 1988;241:540e5.

[5] Kaplan GA, Salonen JT, Cohen RD, Brand RJ, Syme SL, Puska P. Social connections and mortality from all causes and from cardiovascular disease: prospective evidence from eastern Finland. Am J Epidemiol 1988;128:370e80.

[6] Kawachi I, Berkman LF. Social ties and mental health. J Urban Health 2001;78:458e67.

[7] Seeman TE. Social ties and health: the benefits of social integration. Ann Epidemiol 1996;6:442e51.

[8] Inoue S, Yorifuji T, Takao S, Doi H, Kawachi I. Social cohesion and mortality: a survival analysis of older adults in Japan. Am J Public Health 2013;103:e60e6.

[9] Ford ES, Loucks EB, Berkman LF. Social integration and concentrations of C-reactive protein among US adults. Ann Epidemiol 2006;16:78e84.

[10] Ertel KA, Glymour MM, Berkman LF. Effects of social integration on preserving memory function in a nationally representative US elderly population. Am J Public Health 2008;98:1215e20.

[11] Berkman LF, Glass T, Brissette I, Seeman TE. From social integration to health: Durkheim in the new millennium. Soc Sci Med 2000;51:843e57.

[12] Schulz AJ, Mentz G, Lachance L, Johnson J, Gaines C, Israel BA. Associations between socioeconomic status and allostatic load: effects of neighborhood poverty and tests of mediating pathways. Am J Public Health 2012;102:1706e14.

[13] Bird CE, Seeman T, Escarce JJ, Basurto-Davila R, Finch BK, Dubowitz T, et al. Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. J Epidemiol Community Health 2010;64:860e5.

[14] Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto JJ, et al. Neighborhood of residence and incidence of coronary heart disease. N Engl J Med 2001;345:99e106.

[15] Merkin SS, Basurto-Davila R, Karlamangla A, Bird CE, Lurie N, Escarce J, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. Ann Epidemiol 2009;19:194e201.

[16] Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. Science 1997;277:918e24.

[17] Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County Study. Am J Epidemiol 1999;149:898e907.

[18] Evans GW, Kim P. Multiple risk exposure as a potential explanatory mechanism for the socioeconomic status-health gradient. Ann N Y Acad Sci 2010;1186:174e89.

[19] Diez Roux AV. Conceptual approaches to the study of health disparities. Annu Rev Public Health 2012;33:41e58.

[20] Diez Roux AV. Towards a realistic and relevant public health: the challenges of useful simplification. J Public Health 2008;30:230e1. discussion 2e3.

[21] Berkman LF. Social epidemiology: social determinants of health in the United States: are we losing ground? Annu Rev Public Health 2009;30:27e41.

[22] House JS, Umberson D, Landis KR. Structures and processes of social support. Annu Rev Sociol 1988;14:293e318.

[23] Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. Am J Public Health 2006;96:2145e53.

[24] O ′Campo P, Wheaton B, Nisenbaum R, Glazier RH, Dunn JR, Chambers C. The Neighbourhood Effects on Health and Well-being (NEHW) study. Health Place 2015;31:65e74.

[25] Campbell KE, Lee BA. Sources of personal neighbor networks: social integration, need, or time? Soc Forces 1992;70:1077e100.

[26] Almeida J, Molnar BE, Kawachi I, Subramanian SV. Ethnicity and nativity status as determinants of perceived social support: testing the concept of familism. Soc Sci Med 2009;68:1852e8.

[27] Small ML. Racial differences in networks: do neighborhood conditions matter? Soc Sci Q 2007;88:320e43.

[28] Marcus AF, Echeverria SE, Holland BK, Abraido-Lanza AF, Passannante MR. How neighborhood poverty structures types and levels of social integration. Am J Community Psychol 2015;56:134e44.

[29] Keene D, Bader M, Ailshire J. Length of residence and social integration: the contingent effects of neighborhood poverty. Health Place 2013;21:171e8.

[30] Stringhini S, Berkman L, Dugravot A, Ferrie JE, Marmot M, Kivimaki M, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. Am J Epidemiol 2012;175:1275e83.

[31] Barger SD. Social integration, social support and mortality in the US National Health Interview Survey. Psychosom Med 2013;75:510e7.

[32] National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Household Adult Data File and Documentation. In: USDHHS. Hyattsville, MD: Centers for Disease Control and Prevention; 1996.

[33] National Center for Health Statistics. The Third National Health and Examination Survey (NHANES III) Linked Mortality File, Mortality Follow-up through 2006: Matching Methodology. In: USDHHS. Hyattsville, MD: US Department of Health and Human Services; 2009.

[34] National Center for Health Statistics. National Health and Nutrition Examination Survey (1988-1994) Documentation, Codebook, and Frequencies: Geocoding (N3_GEO). In: USDHHS. Hyattsville, MD: US Department of Health and Human Services; 2009.

[35] The Public Health Disparities Geocoding Project. U.S. Census Tract Poverty Data. Boston, MA: Harvard School of Public Health; 2004. Available at: http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm [accessed February 4, 2016].

[36] Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: the Public Health Disparities Geocoding Project. Am J Public Health 2005;95:312e23.

[37] Obisesan TO, Gillum RF. Cognitive function, social integration and mortality in a U.S. national cohort study of older adults. BMC Geriatr 2009;9:33.

[38] Galea S, Tracy M, Hoggatt KJ, Dimaggio C, Karpati A. Estimated deaths attributable to social factors in the United States. Am J Public Health 2011;101:1456e65.

[39] Pantell M, Rehkopf D, Jutte D, Syme SL, Balmes J, Adler N. Social isolation: a predictor of mortality comparable to traditional clinical risk factors. Am J Public Health 2013;103:2056e62.

[40] Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. Am J Public Health 2005;95:260e5.

[41] Krieger N. A century of census tracts: health & the body politic (1906e2006). J Urban Health 2006;83:355e61.

[42] Bishaw A. Areas with Concentrated Poverty: 2006-2010. In: USDOC. Washington, DC: US Census Bureau; 2011.

[43] Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic status in health research: one size does not fit all. JAMA 2005;294:2879e88.

[44] Persson I. Essays on the assumption of proportional hazards in Cox Regression. Department of information science. Uppsala, Sweden: Uppsala University; 2002.

[45] Knol MJ, VanderWeele TJ, Groenwold RH, Klungel OH, Rovers MM, Grobbee DE. Recoding preventive exposures to get valid measures of interaction on an additive scale. Eur J Epidemiol 2011;26:825e6.

[46] Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. Int J Epidemiol 2012;41:514e20.

[47] Knol MJ. Spreadsheet for measures of additive interaction with confidence intervals and p-values using the delta method. Utrecht, The Netherlands: Julius Center; 2011.

[48] Shah VB, Bieler GS. SUDAAN User's Manual. Research Triangle Park, NC: Research Triangle Institute; 2005.

[49] Glymour MM, Osypuk TL, Rehkopf DH. Invited commentary: off-roading with social epidemiology–exploration, causation, translation. Am J Epidemiol 2013;178:858e63.

[50] Seeman TE, Kaplan GA, Knudsen L, Cohen R, Guralnik J. Social network ties and mortality among the elderly in the Alameda County Study. Am J Epidemiol 1987;126:714e23.

[51] Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. PLoS Med 2007;4:e297.

[52] Frieden TR. A framework for public health action: the health impact pyramid. Am J Public Health 2010;100:590e5.

[53] Krieger N. Methods for the scientific study of discrimination and health: an ecosocial approach. Am J Public Health 2012;102:936e44.